CONTROL OF THE CRANE OF A FOREST MACHINE DURING DRIVING

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to a method for controlling the position of a knuckle boom crane during movements of a forest working machine. The invention relates to a forest working machine.

2. Description of the Related Art

For harvesting, forest working machines, such as harvesters, are known which move on a terrain and in which a manipulating apparatus, a so-called harvester head, is arranged at the end of a crane and is intended for cutting, felling and delimbing a standing trunk and sawing it to pieces of desired length. The harvester head is provided with the necessary feeding and sawing means for manipulating the trunks. The sawed trunks are collected with another known working machine that moves on the terrain, and its manipulating device, wherein the working machine in question is a forwarder equipped with a loading grapple, and the trunks are transported in its load space. Combined machines are also known, in which the functions of the harvester and the forwarder are combined.

The combined machines, harvesters and forwarders typically comprise two successive frame structures, which are arranged, by means of a frame joint, to swivel around a vertical axis in relation to each other and/or to swivel around a horizontal axis in relation to each other. In forwarders, the front frame is normally carried by one pair of wheels or two swinging bogie structures with two wheels each. The cabin and the power source are normally placed on top of the front frame. The rear frame is typically carried by two swinging bogie structures with two wheels each. Alternatively, each wheel is connected to the rear frame by a separate suspension, as in US patent 5,366,337 or 6,299,181.

On top of the rear frame, a load space is placed, as well as a crane which is generally of the type of a knuckle boom whose outermost end typically comprises a telescopic unit with a grapple. The crane on the rear frame is typically connected directly behind the frame joint, in front of the load space, wherein it is simultaneously placed behind the cabin. One such forwarder is Timberjack™ 1010B or Timberjack™ 1110C. The crane, in turn, is placed on top of a swivelling device, by means of which the crane can be swivelled around a vertical axis during manipulation of loads by the side of the forwarder. When the crane is not in use, for example during driving of the forwarder, it lies on the bottom of the load space or on top of the load, against which the grapple, the outermost end or the outermost ends of the crane are supported. Typically, the grapple of the crane is gripping either the outermost trunks or the bottom of the load space, its rear part.

The crane and its swivelling device may also be placed in the rear part of the front frame, wherein it is placed on top of the cabin or in front of the frame joint, typically behind the cabin, as in US patent 3,450,222. One such forwarder is Timberjack™ 810B. Also in this case, the outermost end of the crane lies in the load space during normal driving.

In harvesters, the crane is typically placed in the front part of the front frame, in front of the cabin, and the power source is placed on the rear frame. In some special devices, as in US patents 4,505,396 and 4,506,792, a processing unit is also placed on the front frame, for example for delimbing and cutting of trunks. Said US patents also present means for directing the cabin and the crane in the same direction during working. The orientation of the cabin towards the harvester head is also discussed in application EP 1 201 832 A1.

When the forwarder is used to transport a load or is driven unloaded in the terrain or on a road, the crane is normally not in use but it lies on top of the load or in the load space, even in such a way that the grapple is not connected to anything. In such a case, a so-called floating engagement is turned on in the pressurized medium system of the swivelling device of the crane, allowing the crane to swivel freely around the vertical direction. The aim is that the position of the crane is

not rigid or locked in relation to the front frame, because otherwise the crane, swinging with the front frame, would move considerably in relation to the rear frame. When the swivelling device of the crane floats freely, the crane and the grapple swing to a lesser extent in relation to the rear frame, because the end of the crane lies in the load space or on top of the load and thus tends to remain stationary.

However, the problem is that the end of the crane still moves to a great extent in relation to the rear frame, particularly when the forest working machine is tilted. The tilting is caused, for example, by crossing an obstacle or driving in a slope. The slanted crane is swivelled by gravity, because said neutral engagement is used and the forces keeping the grapple stationary are exceeded by the effect of gravity. As a result, the grapple moves on the bottom of the load space or on top of the load also when the grapple is gripping trunks.

SUMMARY OF THE INVENTION

It is an aim of the present invention to present a way of minimizing or totally eliminating the disadvantages caused by the movement of the crane. In particular, the aim is to have an active effect on the behaviour of the crane and to use the control to prevent any unnecessary movement of the crane when the forest working machine is moving. In an advantageous embodiment, the particular aim is to keep the grapple, or the part of the crane which lies in the load space of the forwarder, as stationary as possible.

One embodiment of the invention is also suitable for some harvesters with no load space, wherein the position of the crane can be automatically controlled during driving. Thus, the driver does not need to take care that, for example, the crane mounted on the front frame remains substantially in the same position and direction in relation to the rear frame, when the crane is swivelled above the rear frame, or *vice versa*. Thus, the total length of the harvester can be reduced and the manipulation in the terrain becomes easier. According to prior art, the crane of the harvester cannot be turned in such a way (about 180°) that

it would extend onto the rear frame, wherein it is normally above the front frame.

Thanks to the invention, it is possible to minimize the movement of the whole crane, its outermost end, the grapple, or any part lying in the load space or on top of the load in the forwarder. In the invention, the control of the swivelling device of the crane depends on the angular position between the front frame and the rear frame. The unnecessary movement of the crane is also prevented when driving in a slope and when crossing obstacles. The operation of the invention can be improved by coupling other joints of the crane in so-called free floating. The invention is also useful during driving on a flat surface, because when driving in a curve, the centrifugal forces cannot cause swinging of the crane to the side, even though the driving speed were high and the position of the forest working machine were changed.

In one embodiment of the invention, no part of the crane lies on top of the structures of the load space, on the load, or on the rear frame, but active control is still in use, and the crane with its tools is placed in a given position above the load space or the rear frame. The advantage is thus that when the working machine is driven in a curve, the driver does not also need to continuously take care of swivelling the crane in such a way that it does not hit structures of the working machine, for example a bunk or stakes, or trees growing by the side of its driveway.

The control system, operated by pressurized medium, can also be easily implemented by using a small number of control valves to interconnect the control circuits of the pressurized medium systems of the swivelling device and the frame joint, and by controlling said valves with the control system of the forest working machine, such as, for example, the Timberjack TMC™ system.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following, the invention will be described in more detail by using a preferred embodiment as an example, wherein reference is at the same time made to the appended drawings, in which:

Fig. 1 shows the principle of a forwarder in a top view, when driving straight ahead,

Fig. 2 shows the forwarder of Fig. 1 when driving in a curve and when the crane turns with the front frame,

Fig. 3 shows the forwarder of Fig. 1 when driving in a curve and when the crane is actively controlled,

Fig. 4 shows the principle of a harvester, in a top view, when driving in a curve and when the crane is actively controlled, and

Fig. 5 shows a control system for actively controlling the crane.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 shows a forest working machine which is a forwarder whose assembly and principle correspond to the structure of, for example, the Timberjack™ 810C forwarder. This forwarder 1 comprises a front frame 2 and a rear frame 3 which are interconnected by means of a frame joint 4, wherein the frames can pivot around the vertical axis and preferably also swivel around the horizontal axis joining the longitudinal direction 13 of the forwarder which, in Fig. 1, is simultaneously the driving direction of the front frame 2. In some cases, the frame joint 4 also allows the turning of the frames around the horizontal axis which is transverse to the direction 13. The structure and operation of the frame joint 4, as well as the structure of the frames, are known as such.

In the forwarder of Fig. 1, the front frame 2 is supported by swinging bogies 5 and 6 with two wheels each, and the rear frame 3 is supported by swinging bogies 7 and 8 with two wheels each. The structure of the bogies is known as such, and the number of the wheels may vary, as presented above. The bogie can be replaced by independent wheel suspensions, and chain tracks may also be connected to the wheels, or they may be replaced by caterpillar tracks.

The front frame 2 is provided with a cabin 9, and behind the cabin, a crane 10 is mounted on the front frame 2 by means of a swivelling device 11. The swivelling device 11 forms a kind of a traverser, onto which the crane 10 is mounted and which can pivot around a vertical axis of rotation. Thanks to the swivelling, the grapple 12 of the crane 10 can be extended to the sides of the forwarder 1, wherein the grapple 12 can be used for loading or unloading of timber and trunks. The crane 10 can also be provided with a harvester head instead of the loading grapple 12. In Fig. 1, the crane 10 comprises a vertical pillar 10a, primarily a horizontal boom 10b and an outermost boom 10c, which are pivoted in relation to each other, around the horizontal axis, and the outermost boom 10c consists of three parts and operates telescopically, and its end is provided with a tool, such as the grapple 12. Alternatively, the crane only comprises three or four boom parts, and the grapple 12 is connected to the end of the outermost boom part. Normally, the pillar 10a cannot be tilted forward or backward.

In Fig. 1, the outermost boom 10c is bent under the horizontal boom 10b, wherein the end of the outermost boom 10c is, this time, closer to the front end than the rear end of the rear frame 3. The grapple 12 can also be used to grip the structures of the load space 20 at a desired location, normally its rear part, at the point 12b. The grapple 12 lies on top of the rear frame 3 or the load in the load space 20. Alternatively, the grapple 12 is placed above the load space 20, at a distance from the bottom of the load space 20 or from the load.

Figure 1 also shows the driving direction 13 of the front frame 2, the driving direction 14 of the rear frame 3, and the direction 15 of the crane 10, which directions are, in this case, joined, when driving straight ahead. The direction 15 of the crane also indicates the position of the horizontal boom 10b or the direction in which the grapple 12 is placed, seen from the direction of the swivelling device 11. As seen, the crane 10 extends backwards from the front frame 2.

Figure 2 shows what happens when the forwarder 1 is driven in a curve, or the driving direction 13 of the front frame is changed. This corresponds to a situation in which the neutral, inactive floating

engagement is used in the control system and the swivelling device 11, wherein the crane 10 is swung to the side by the centrifugal forces, which was the problem of prior art. In this case, the direction 15 of the crane and the direction 13 of the front frame remain the same, wherein the grapple 12 moves considerably from its original position 12a. This position also corresponds to the position in which the swivelling device 11 is locked in a given position complying with Fig. 1, wherein in a curve, the crane 10 is forced to swivel to the side in the position corresponding to Fig. 2. For this reason, locking is not a good alternative.

The quantity of the free swinging of the crane 10, *i.e.* the angular position C of the direction 15 in relation to the direction 14, will vary and depend *e.g.* on the forces effective on the grapple 12. Similarly, the crane 10 swings to the side when the tilted forwarder 1 is driven in a slope, although it would be driven straight ahead. The reference position 12a of the crane 10 can also be at the side of the central line, and the corresponding angular position of the swivelling device 11 is simultaneously the reference position or the 0 position, in view of the changes.

Figure 3 shows a situation in which the active control of floating is used and when the forwarder 1 is driven in a curve or the driving direction 13 is changed, wherein the direction 14 of the rear frame differs from the direction of the front frame 13 (angular position A). By means of the active control of the swivelling device 11, the position of the grapple 12 differs from its original position 12a as little as possible, and its swinging or moving is prevented or limited to a desired extent. If the place where the grapple 12 is lying is further back than in Fig. 3, the angular position C between the directions 14 and 15 is controlled to be smaller than in Fig. 3. The change in the direction 15 is thus greater, compared with the starting position of Fig. 1. As a result, the end of the boom of the crane 10 will also swing to a lesser extent. The intersection of the directions 14 and 15 is preferably located at the point, or on the same line in the vertical direction, where the grapple 12 or a part of the crane 10 lies in the load space 20 or on top of the load, to make the movement as small as possible. Alternatively, or additionally, it is possible to keep that part of the crane 10 which is located outermost from the

swivelling device 11, on the line 14 or, at the most, at a desired distance from the same. In this way, it is possible to avoid the movement of the end of the crane 10 to the side of the forwarder 1, when driving in a sharp curve. The rotational angle of the swivelling device 11 of the crane 10 (rotary position B which is the difference between the directions 13 and 15) is dependent on the angular position between the frames 2 and 3 (position A, which is the difference between the directions 13 and 14).

The turning direction of the swivelling device 11 is also opposite to the turning direction of the front frame 2 or the frame joint 4. It can be stated that the rotational angle B of the swivelling device 11, or its change, is normally smaller than the rotational angle A of the front frame 2 or the frame joint 4, or its change. The correlation can be defined as a parameter X which indicates the relation between the angular position A and the angular position B. The correlation X can also be defined on the basis of the change in said angular positions in relation to a selected reference position. Alternatively, the correlation is defined by means of geometry, for example on the basis of the point in the crane 10 that is to be kept as close to a given point in the rear frame 3 as possible. Examples of said points include the grapple 12 and its reference position 12a. The correlation can also be selected empirically. If necessary, it is possible to define that the rotational angles A and B correspond to each other ($X = 1$), wherein the crane 10 is always parallel to the rear frame 3. This is a useful alternative during short movements and working of the forwarder, particularly when no part of the crane 10 lies in the load space 20, because otherwise the grapple 12 would move on top of the load space.

When the forwarder 1 is driven straight ahead, then, thanks to the active control, the crane 10 cannot swing to the side even though one were driving in a slope or it were tilted during crossing of an obstacle. The crane 10 is kept in the desired reference position, *i.e.* in the desired angle B. The position of the crane 10 is changed, if the angular position between the frames is simultaneously changed.

Figure 5 shows the control system 18 for implementing the floating. The swivelling device 11 of the crane is known as such, and it generally comprises two mechanical cylinders 11a and 11b, which are operated by a pressurized medium and which rotate a structure used as a traverser onto which the crane 10 is mounted or which is an integral part of the crane 10. For example, it is known to use a combination of a toothed bar (in the cylinder 11a and 11b) and a toothed wheel (in the traverser) for the transmission.

If necessary, the swivelling device 11 can be switched on so-called neutral, uncontrolled floating, for example by means of valves 18a, in a way known as such. This is, for example, an electrically controlled, normally closed 2/2-directional valve which opens a connection between the chambers of different ends of the same cylinder (11a and 11b). The control circuit of the pressurized medium system 18b comprises the necessary pressure source, tank, and controllable valve means. The pressurized medium is led to the working chamber via a pipework and valves, and back to the tank or the control circuit.

The system 18 comprises an electric control device 18c which can be preferably modified by programming and which controls the working machine as well as all the auxiliary functions related to the same. The control device 18c also informs about the operation of the machine by means of a display in the cabin, and via a user interface 19, various settings and adjustments, which may also be driver-specific, can be stored in the system. The control device 18c is also programmed to implement the function according to the invention, which modification work as such will be obvious for a person skilled in the art on the basis of this description. The second embodiment of the invention, which is based on the use of sensors, is easy to implement merely by modifications in the control device 18c. The swivelling device 11 is thus controlled on the basis of information from the sensors but by using valves known as such, for example the first proportional directional valve of the pressurized medium circuit 18b, wherein the entry of pressurized medium in the actuators is controlled. The pressurized medium, in turn, produces the force effect of the actuator.

In the first embodiment of the invention, the actuators 4a, 4b (*e.g.* cylinders) of the frame joint 4 and the actuators 11a, 11b of the swivelling device are coupled in series, if needed, for example by the pressurized medium circuit 18d shown in Fig. 5, by using, for example, electrically controlled, normally closed 2/2 directional valves (as well as 3/2 directional valves), wherein the second proportional directional valve of the system 18b, which controls the function of the frame joint 4, simultaneously controls the swivelling position of the swivelling device 11. When the frames 2 and 3 are turned, the actuators 4a and 4b, coupled in parallel, move in different directions and the angular position is changed. The actuators 4a and 4b can be mounted directly between the frames 2 and 3, but the turning can also be implemented in such a way that the actuators are coupled between the frame joint 4 and the frame to be turned.

The correlation or mathematical relation between the angular position and the rotary position is defined as parameter X in the control device 18c where it can be changed and where it can be stored. In the second embodiment of the invention, the separate circuit 18d will not be necessary, but the control device 18c uses said proportional valve to control the position of the crane 10 depending on the angular position. The angular position is defined, for example, by sensors. In the first embodiment, the correlation X is bound and is only based on the settings of the pressurized medium system 18d or the dimensions of the components. When the actuators 4a (or 4b) and 11a (or 11b) are cylinders coupled in series, the transmission ratio, *i.e.* the parameter X, is selected by suitable dimensioning the ratio between the surface areas of their pistons, considering the volume flows to be transferred. For example, the relation X corresponds to the position 12b in Fig. 3. If the relation is to be changed, the circuit 18c is used either to reduce (smaller turning movement) or to increase (greater turning movement) the volume flow to be transferred to the swivelling device 11. For the control, suitable control valves are used, for example flow divider valves. According to a third embodiment of the invention, the control device 18c controls said volume flow in the above-described manner. Preferably, said ratio can be freely defined, either in the control device

18c or by means of adjustments of the components 18d, depending on the type of the crane 10 and on the desired function.

In the control device 18c, it is possible to select alternatives representing different positions of the crane 10, on the basis of which said correlation is also determined. If desired, the crane 10 can be driven manually, or also automatically by means of the control system 18, to a reference position, in relation to which the changes in the rotary position 15 are implemented. The reference position complies, for example, to Figs. 1 or 4. If the frames 2 and 3 are thus swivelled, this can be taken into account by the control by using the sensor 17 to compensate for the position error in relation to the position of Fig. 1. The driver switches the active floating on or off in the given situation by using, for example, the user interface 19.

Figure 5 also shows sensors 16 and 17 which are not compulsory in the first embodiment of the invention. The control system 18 monitors the angle or position between the frames 2 and 3, for example, by means of a signal from an angular or position sensor 17. The position can be determined on the basis of the frame joint 4 or one of its cylinders 4a or 4b, or on the basis of the position of any other suitable part. The position of the crane 10 is determined on the basis of the signal from the angular or position sensor 16, wherein its position is known. The sensor is preferably placed in the swivelling device 11. Thus, the crane 10 is perhaps already placed on top of the load space 20, but it may be that the crane 10 extends outside the load space 20, wherein it must first be brought, manually or automatically, to a desired reference or starting position above the load space 20. The reference position generally corresponds to the direction 15 of Fig. 1. For the control 19, either a desired relation X is defined, or it is determined which part of the crane 10 is to be kept stationary. If the crane 10 or the grapple 12 has one or more standard positions in which they are kept, it is possible to select a separate, predetermined relation X for each standard position. If, at first, the crane 10 is set manually in the given position, and the active floating control is then switched on, the sensor 16 will not be necessary. However, the sensor 16 makes it possible to check the position of the crane 10 and to monitor if the crane 10 has

reached the correct position during the control, and in this way, automatic return to the initial position is also possible.

The rotary position 15 of the crane 10 is preferably changed simultaneously when the frames 2 and 3 are swivelled, wherein *e.g.* the grapple 12 is moved as little as possible. The crane 10 is kept stationary when the position of the frames is not changed.

The changes or amendments required in the control system 18 can be implemented by a person skilled in the art on the basis of this description, and they can be modified depending on the more detailed structure and type of the forest working machine in question. The type and mode of action of the sensors 16 and 17 can be selected, and they are determined on the basis of the type of the swivelling device 11 or the frame joint 4 used. Almost any generated signal can be used, as long as it indicates the angular positions of the frames 2 and 3 and the angular difference between the same.

The crane 10 normally comprises an actuator, *i.e.* a cylinder, which is coupled between the pillar 10a and the boom 10b. In one embodiment of the invention, in which the grapple 12 lies either on top of the load or on the load space, this actuator 10d is switched to floating, wherein the horizontal boom 10b can rise or descend freely. The pillar 10a is fixed in the vertical position. This is advantageous particularly in situations, in which the front frame 2 is also pivoted in relation to the rear frame 3, for example when the wheels 5 (or 6) of the front frame 2 are crossing a small hillock. If said cylinder is locked, the grapple 12 will move slightly in relation to the rear frame 3, because the front frame 2 and thereby the crane 10 are tilted, in spite of the active control. The control system 18 takes care of controlling the floating simultaneously with the control of the swivelling device.

Figure 4 shows the application of the invention in a forest working machine 1 which is a harvester. The numbering of the parts and the directions corresponds to the numbering in the other drawings, but the harvester 1 does not comprise any load space, and the swivelling device 11 is typically placed foremost in the front frame 2; similarly, the

power source is generally on top of the rear frame 3. In this case, the crane 10 is placed in such a way that it is at a distance above the rear frame 3, wherein the function discussed in connection with Fig. 3 and the above-presented principles of control are valid also in this case. Normally, the rear frame 3 of the harvester 1 does not comprise a place where the grapple 12 or the crane could lie, but with the invention, it is now possible to place one there. This location may also be provided with means for fixing the grapple. The crane 10 is not oriented forwards, as normally, and thereby it does not take space during driving in a curve. Also, the driver does not need to monitor the movements of the outermost end of the crane 10, if this part is defined to be such that it moves as little as possible in the lateral direction.

The invention is not limited solely to the above-presented embodiment, but it can be implemented within the scope of the appended claims.